

**LEAD SOIL TREND ANALYSIS
THROUGH JULY 2005**

EVALUATION BY INDIVIDUAL QUADRANT

**Herculaneum Lead Smelter Site
Herculaneum, Missouri**

Tetra Tech EM Inc. (Tetra Tech) was tasked by the U.S. Environmental Protection Agency (EPA) Region 7 Enforcement/Fund Lead Removal program to conduct a trend analysis of soil lead concentrations at selected locations within Herculaneum, Missouri (City). Specifically, the Tetra Tech Superfund Technical Assessment and Response Team (START) 2 was requested to review and analyze data that would enable EPA to determine whether soil lead concentrations were increasing over time at a variety of locations within the City. The assessment was conducted under the authority of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 and the Superfund Amendments and Reauthorization Act of 1986. The project was assigned under START Contract No. 68-S7-01-41, Task Order No. 0027.

Tetra Tech focused its analysis on one data set called "Recontamination." This data set includes results from a number of residential properties. The data were collected from four different quadrants at each property, and additional data for several properties came from samples collected in driveway areas outside the quadrants. Lead concentrations were estimated at each location at approximately monthly intervals from the time removal activities were completed until July 2005 (sampling round 21). Because of the sequence of removal activities, not all properties underwent the same number of sampling events; the number of events ranged from 4 to 15 events per quadrant for individual properties. At many locations, some intervals within the series were omitted because weather or access restrictions prevented data collection. The lead concentrations were determined by use of a portable X-ray fluorescence (XRF) instrument. Samples were collected and analyzed in accordance with the quality assurance project plan (QAPP) dated September 11, 2001.

This document presents the methods used to evaluate changes in soil lead concentrations following the removal activities, and the results of this analysis.



Methods

Trend tests were conducted for each property using data collected from round 7 (August 2002) through round 21 (July 2005). The non-parametric Mann-Kendall test was used to evaluate temporal trends for each sampled quadrant at the individual properties. The Mann-Kendall test is a widely used statistical test for detecting monotonic trends (that is, trends that are either increasing or decreasing) in time-series data (Gilbert 1987; Helsel and Hirsch 1992; Gibbons 1994). Because the Mann-Kendall test uses only the relative magnitude of the data rather than their measured values, it has a number of desirable properties: the data need not be normally distributed; and the test is not significantly affected by outliers, missing data, or censored data. Censored data are treated in the Mann-Kendall test by setting all non-detect values to a concentration slightly below the minimum detected concentration. It should be noted that a minimum of four sampling events are required to perform this test, so properties with fewer than four rounds of sampling were not evaluated. Properties not sampled during round 21 were also excluded from the trend analysis.

Results

Temporal trends in lead concentrations for 16 properties are summarized in Table 1 and Figure 1. The trend analysis identified 15 out of 16 properties where at least one quadrant showed a statistically significant increasing trend. No statistically significant decreasing trends were identified at any property. Five properties had increasing lead concentrations in all four quadrants: House Numbers 5, 9, 20, 21, and 22. Four properties had increasing lead concentrations in three of four quadrants: House Numbers 7, 16, 18, and 19. Four properties had increasing lead concentrations in two of four quadrants: House Numbers 3, 24, 101, and 102. House numbers 6 and 76 had only one quadrant with an increasing trend in lead concentration. Only one property, House Number 15, showed no statistically significant trend in lead concentrations. All trend results are depicted graphically in Figure 1. Open symbols are used in Figure 1 to represent censored (nondetect) data, and solid symbols represent detected data.

Trend results reported for soil lead concentrations through sampling round 21 were similar to those reported during the last quarterly period, with the following exceptions. Eight quadrants from six properties that did not show a significant trend in lead concentration from rounds 7 through 20 now show a statistically significant increase in lead concentration with the addition of the data from round 21. The

properties include House Numbers 16 (quadrant 3), 18 (quadrants 1 and 3), 19 (quadrant 2), 21 (quadrants 1 and 2), 22 (quadrant 1), and 76 (quadrant 1). Two properties, House Numbers 12 and 17, were not included in the trend results reported in Table 1 because they were not sampled during round 21. One additional property, House Number 15, appeared in the trend analysis for the first time, as the addition of the round 21 data yielded the minimum of four samples required to conduct the Mann-Kendall trend test. No significant trend in lead concentration was shown for House Number 15.

References:

- Gibbons, R. D. 1994. *Statistical Methods for Groundwater Monitoring*. John Wiley & Sons, Inc. New York, New York.
- Gilbert, R. O. 1987. *Statistical Methods in Environmental Pollution Monitoring*. John Wiley & Sons, Inc. New York, New York.
- Helsel, D. R. and R. M. Hirsh. 1992. *Statistical Methods in Water Resources*. Elsevier. New York, New York.

TABLE 1
RESULTS OF STATISTICAL TESTING FOR MONOTONIC TRENDS (MANN-KENDALL TEST) IN LEAD CONCENTRATION
INDIVIDUAL QUADRANTS FOR SAMPLING ROUNDS 7 THROUGH 21
HERCULANEUM LEAD SMELTER SITE –HERCULANEUM, MISSOURI

Distance From Smelter ¹ (miles)	House Number	Quadrant	Number of Sampling Events ²	Number of Detected Samples	Sampling Event		Mann-Kendall Test Statistic ³ (S)	Probability > S	Trend Significant? ⁴ (Yes/No)	Direction of Trend
					First	Last				
0.10	76	Q1	8	8	10/30/2003	07/07/2005	18	0.016	Yes	Increasing
		Q2	8	8	10/30/2003	07/07/2005	12	0.089	No	N/A
0.20	20	Q1	14	14	08/26/2002	07/07/2005	63	0.001	Yes	Increasing
		Q2	14	14	08/26/2002	07/07/2005	55	0.003	Yes	Increasing
		Q3	14	14	08/26/2002	07/07/2005	63	0.001	Yes	Increasing
		Q4	14	14	08/26/2002	07/07/2005	53	0.003	Yes	Increasing
	101	Q1	7	7	12/22/2003	07/08/2005	9	0.119	No	N/A
		Q2	7	6	12/22/2003	07/08/2005	9	0.119	No	N/A
		Q3	7	7	12/22/2003	07/08/2005	13	0.035	Yes	Increasing
		Q4	7	7	12/22/2003	07/08/2005	15	0.015	Yes	Increasing
	102	Q1	7	7	12/22/2003	07/07/2005	19	0.001	Yes	Increasing
		Q2	7	7	12/22/2003	07/07/2005	7	0.191	No	N/A
		Q3	7	7	12/22/2003	07/07/2005	19	0.001	Yes	Increasing
		Q4	7	7	12/22/2003	07/07/2005	11	0.068	No	N/A
0.25	5	Q1	14	11	08/26/2002	07/08/2005	65	0.000	Yes	Increasing
		Q2	14	13	08/26/2002	07/08/2005	63	0.001	Yes	Increasing
		Q3	14	14	08/26/2002	07/08/2005	58	0.002	Yes	Increasing
		Q4	14	14	08/26/2002	07/08/2005	51	0.005	Yes	Increasing
	6	Q1	14	14	08/23/2002	07/07/2005	29	0.062	No	N/A
		Q2	14	14	08/23/2002	07/07/2005	57	0.002	Yes	Increasing
		Q3	14	14	08/23/2002	07/07/2005	17	0.136	No	N/A
		Q4	14	14	08/23/2002	07/07/2005	19	0.123	No	N/A
	22	Q1	13	13	08/26/2002	07/08/2005	32	0.033	Yes	Increasing
		Q2	13	13	08/26/2002	07/08/2005	40	0.012	Yes	Increasing
		Q3	13	13	08/26/2002	07/08/2005	41	0.010	Yes	Increasing
		Q4	13	13	08/26/2002	07/08/2005	44	0.006	Yes	Increasing
	24	Q1	11	11	11/07/2002	07/07/2005	13	0.129	No	N/A
		Q2	11	11	11/07/2002	07/07/2005	33	0.009	Yes	Increasing
		Q3	11	11	11/07/2002	07/07/2005	19	0.075	No	N/A
		Q4	11	10	11/07/2002	07/07/2005	32	0.011	Yes	Increasing
0.40	21	Q1	10	8	08/23/2002	07/08/2005	20	0.045	Yes	Increasing
		Q2	10	10	08/23/2002	07/08/2005	23	0.023	Yes	Increasing
		Q3	10	10	08/23/2002	07/08/2005	24	0.019	Yes	Increasing
		Q4	10	10	08/23/2002	07/08/2005	35	0.000	Yes	Increasing

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Distance From Smelter ¹ (miles)	House Number	Quadrant	Number of Sampling Events ²	Number of Detected Samples	Sampling Event		Mann-Kendall Test Statistic ³ (S)	Probability > S	Trend Significant? ⁴ (Yes/No)	Direction of Trend
					First	Last				
0.50	15	Q1	4	3	09/16/2002	07/25/2005	2	0.375	No	N/A
		Q2	4	4	09/16/2002	07/25/2005	1	0.500	No	N/A
		Q3	4	3	09/16/2002	07/25/2005	1	0.500	No	N/A
		Q4	4	3	09/16/2002	07/25/2005	4	0.167	No	N/A
	16	Q1	12	8	09/16/2002	07/07/2005	12	0.148	No	N/A
		Q2	12	6	09/16/2002	07/07/2005	47	0.001	Yes	Increasing
		Q3	12	6	09/16/2002	07/07/2005	27	0.032	Yes	Increasing
		Q4	12	8	09/16/2002	07/07/2005	44	0.002	Yes	Increasing
	19	Q1	14	13	08/22/2002	07/14/2005	46	0.010	Yes	Increasing
		Q2	14	11	08/22/2002	07/14/2005	32	0.047	Yes	Increasing
		Q3	14	11	08/22/2002	07/14/2005	28	0.066	No	N/A
		Q4	14	13	08/22/2002	07/14/2005	50	0.005	Yes	Increasing
0.54	9	Q1	14	14	08/22/2002	07/07/2005	50	0.005	Yes	Increasing
		Q2	14	14	08/22/2002	07/07/2005	42	0.016	Yes	Increasing
		Q3	14	14	08/22/2002	07/07/2005	47	0.008	Yes	Increasing
		Q4	14	13	08/22/2002	07/07/2005	44	0.012	Yes	Increasing
0.60	18	Q1	15	15	08/23/2002	07/07/2005	41	0.028	Yes	Increasing
		Q2	15	14	08/23/2002	07/07/2005	31	0.066	No	N/A
		Q3	15	15	08/23/2002	07/07/2005	44	0.021	Yes	Increasing
		Q4	15	15	08/23/2002	07/07/2005	47	0.015	Yes	Increasing
0.75	3	Q1	15	12	08/23/2002	07/07/2005	12	0.172	No	N/A
		Q2	15	13	08/23/2002	07/07/2005	56	0.005	Yes	Increasing
		Q3	15	14	08/23/2002	07/07/2005	19	0.134	No	N/A
		Q4	15	14	08/23/2002	07/07/2005	52	0.008	Yes	Increasing
0.80	7	Q1	15	15	08/23/2002	07/07/2005	28	0.082	No	N/A
		Q2	15	13	08/23/2002	07/07/2005	60	0.003	Yes	Increasing
		Q3	15	12	08/23/2002	07/07/2005	48	0.013	Yes	Increasing
		Q4	15	11	08/23/2002	07/07/2005	69	0.001	Yes	Increasing

Notes:

¹ Properties are ordered as a function of increasing distance from the smelter.

² Trend tests were not conducted for properties with fewer than four rounds of sampling, or for properties not sampled during round 21.

³ All censored (nondetect) measurements were set equal to a concentration slightly lower than the minimum detected value.

⁴ Monotonic trends are significant for probabilities less than or equal to 0.05; significant negative values for the Mann-Kendall test statistic indicate that trends are decreasing; and significant positive values for the Mann-Kendall test statistic indicate that trends are increasing.

NA No significant trend identified.

FIGURE 1. Lead Concentration Trends From Round 7 Through 21

All open circles represent non-detect lead results and all fill circles represent detected lead results.

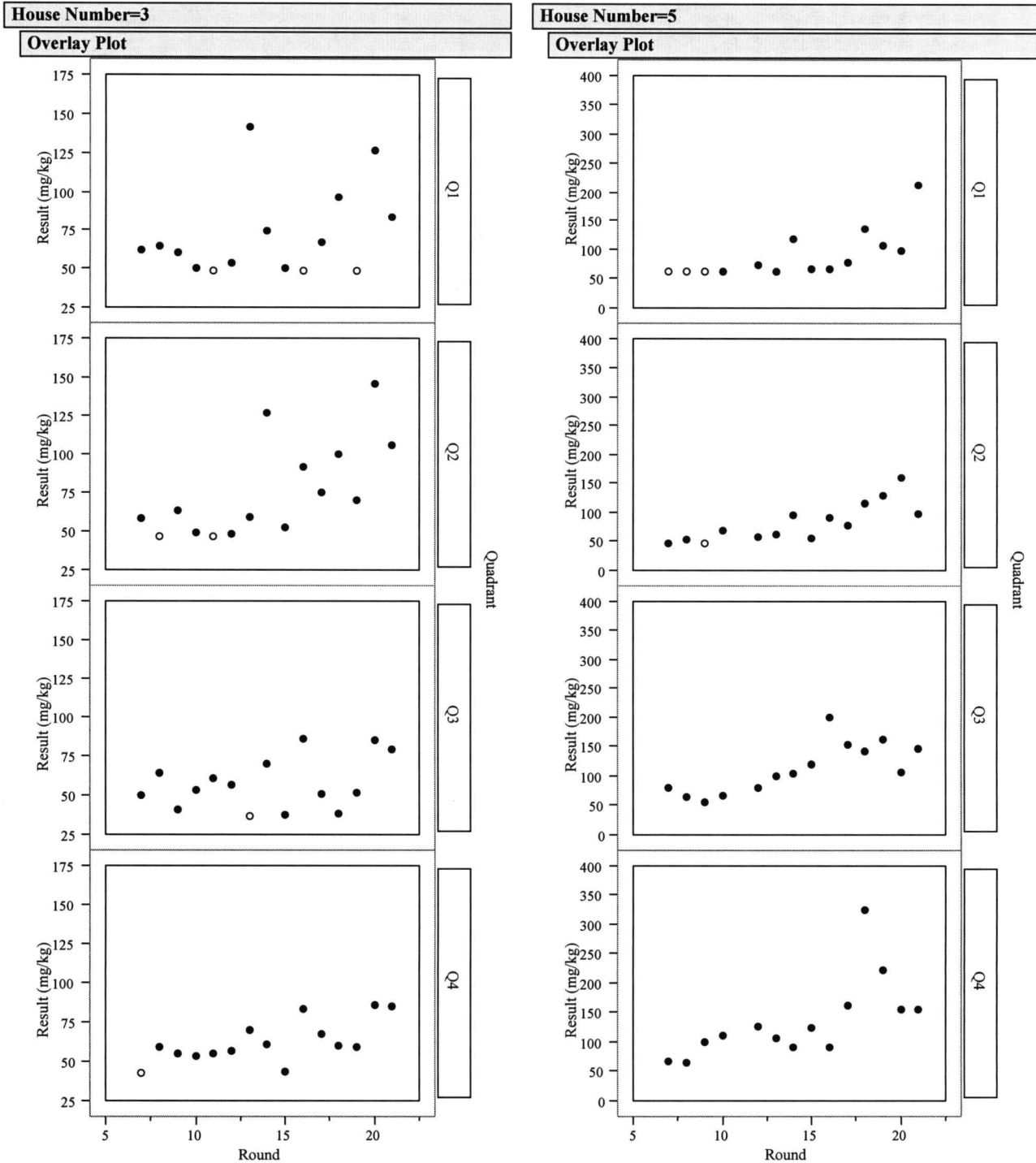


FIGURE 1. Lead Concentration Trends From Round 7 Through 21 (Continued)

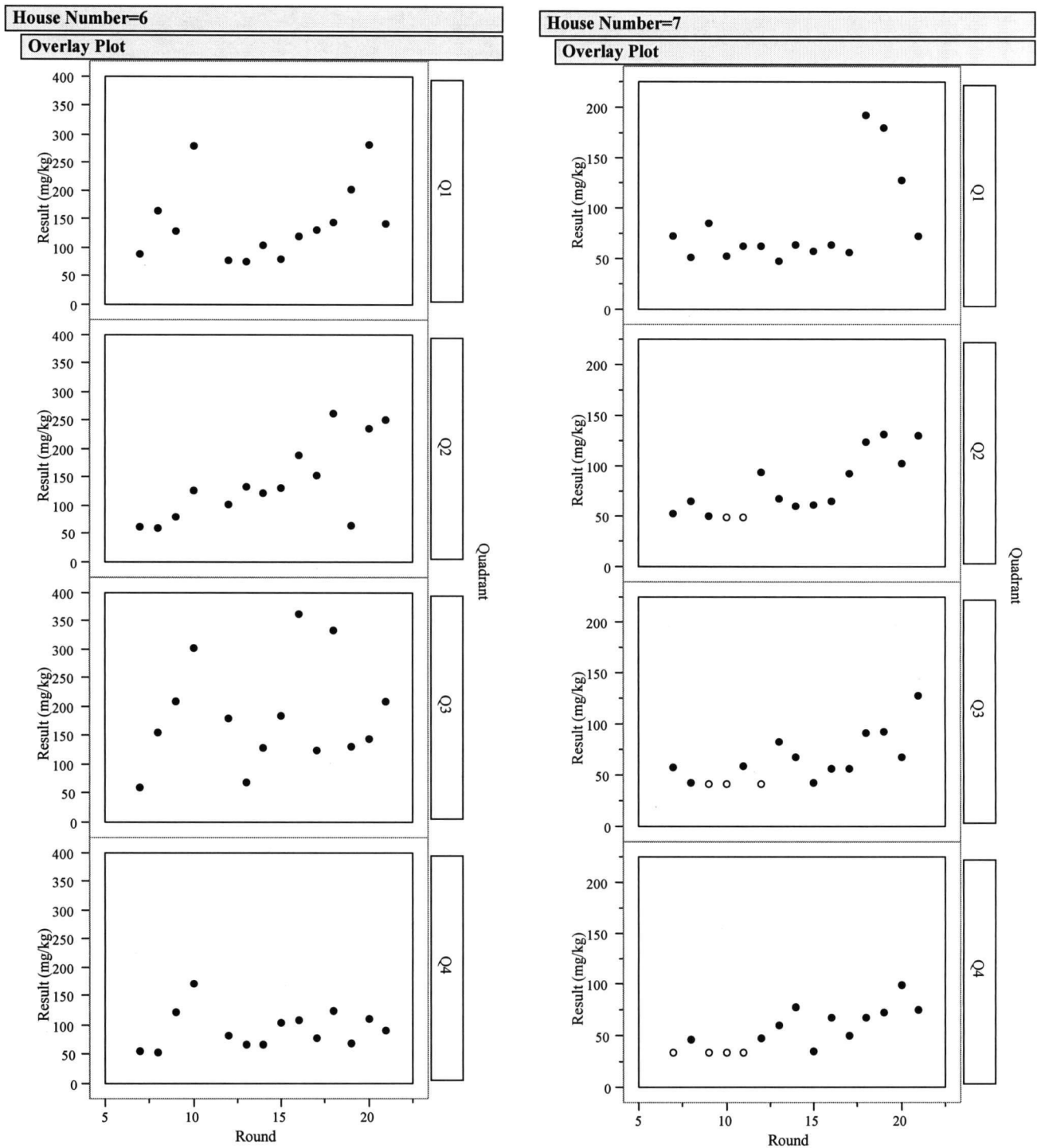


FIGURE 1. Lead Concentration Trends From Round 7 Through 21 (Continued)

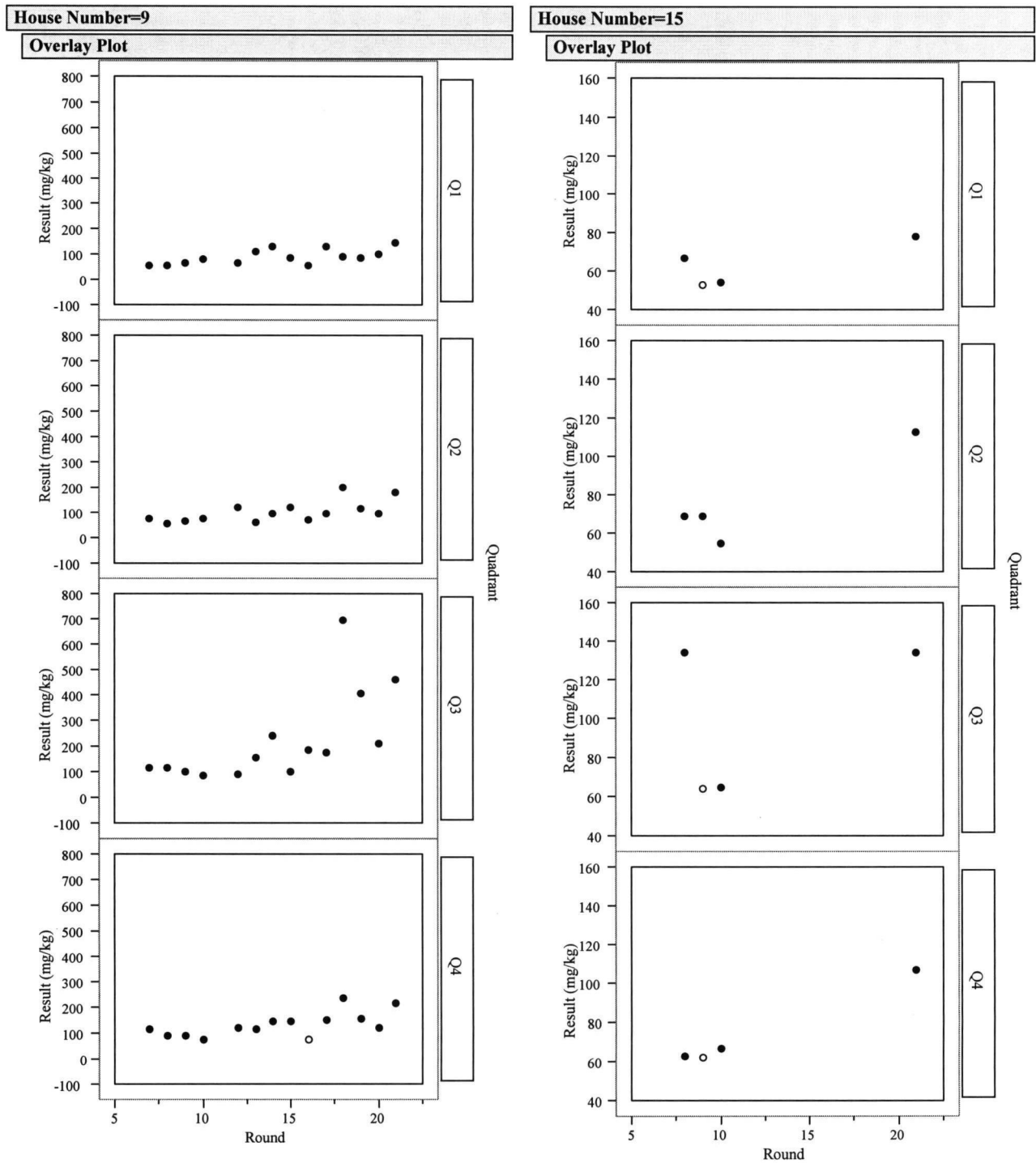


FIGURE 1. Lead Concentration Trends From Round 7 Through 21 (Continued)

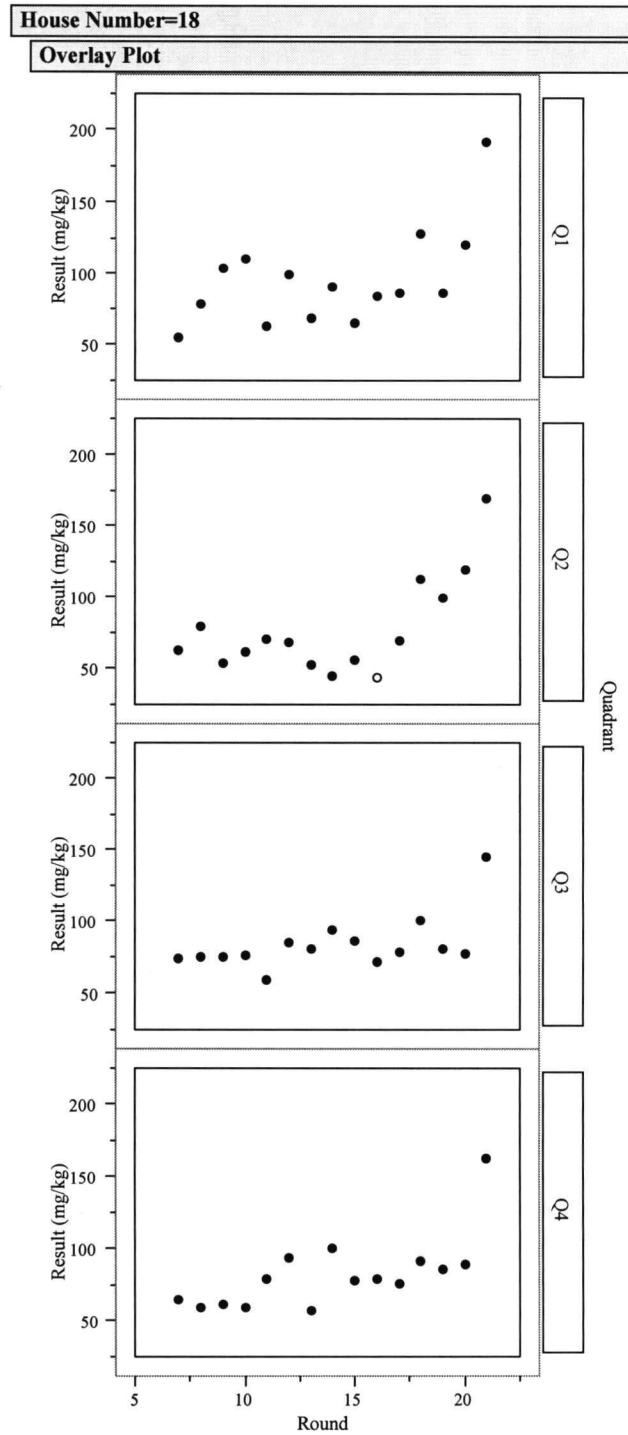
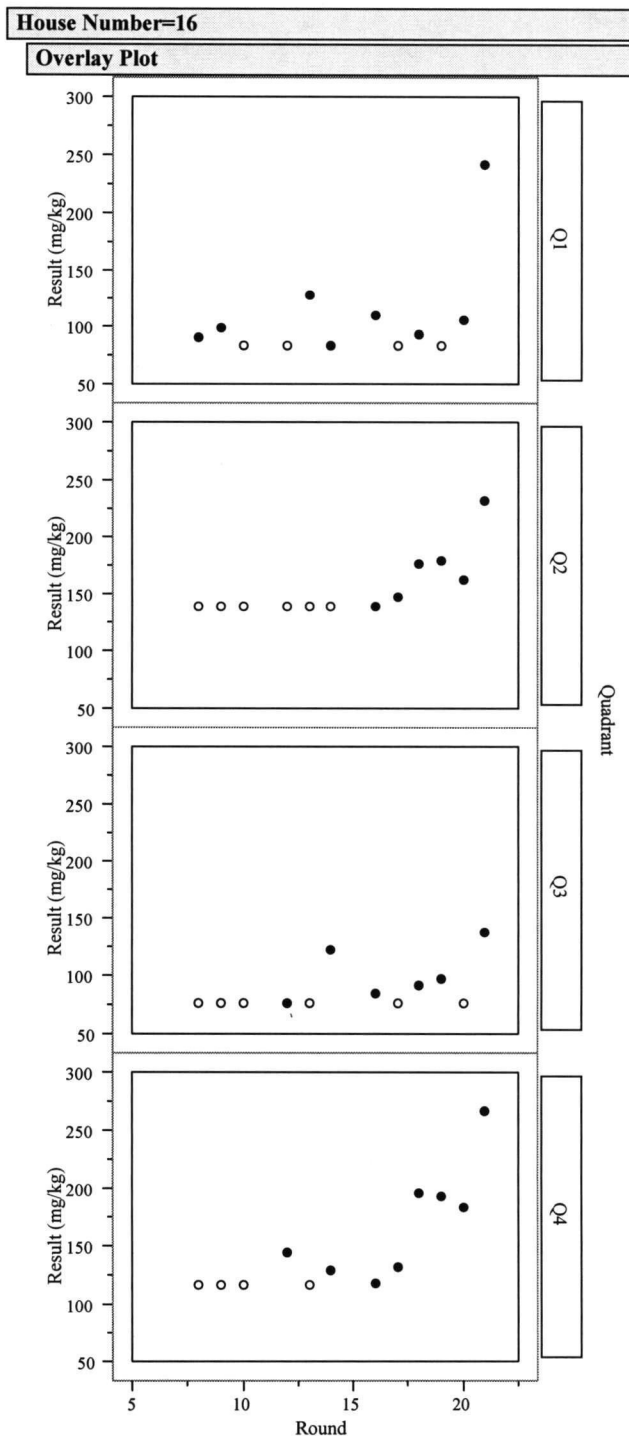


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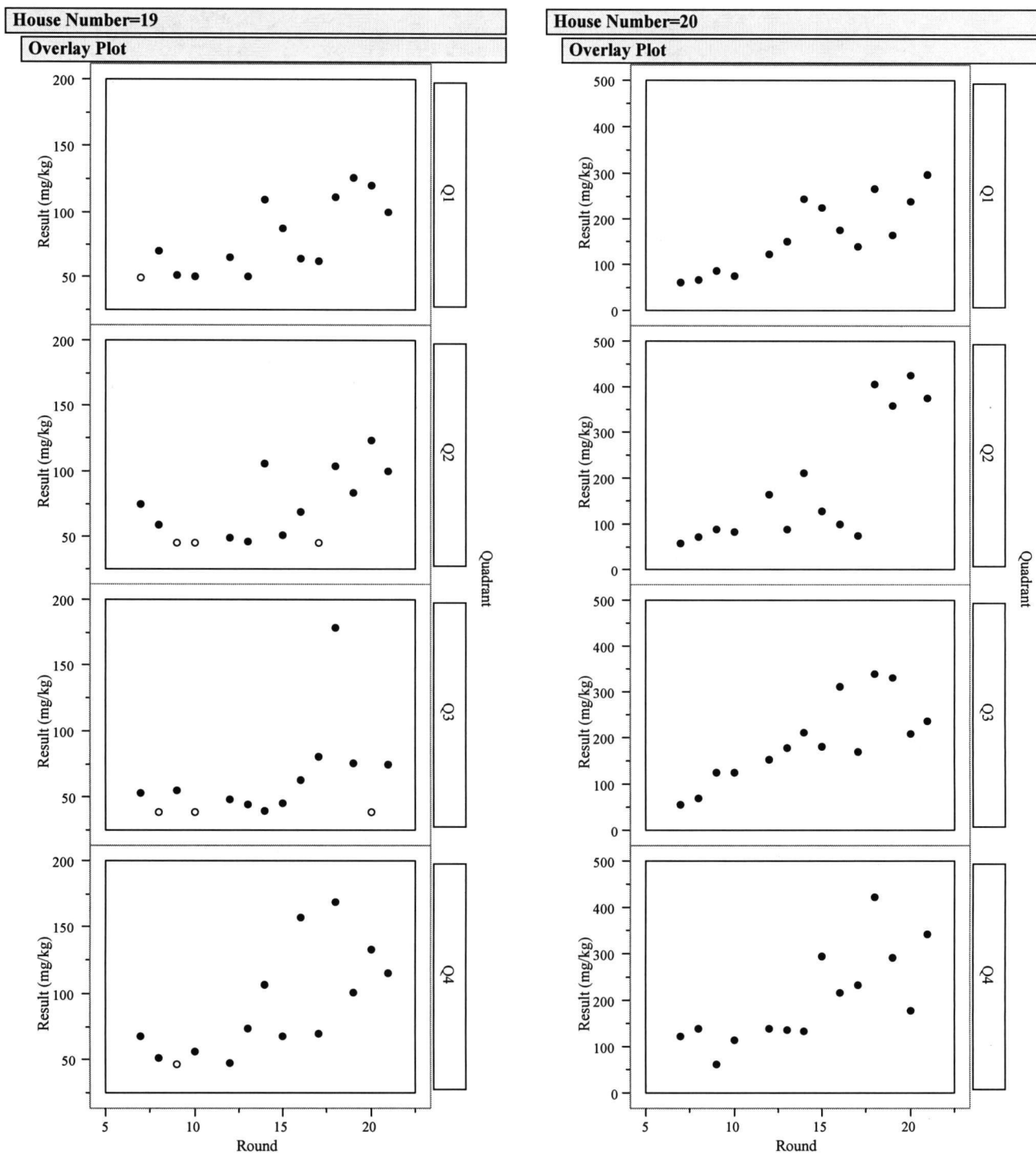


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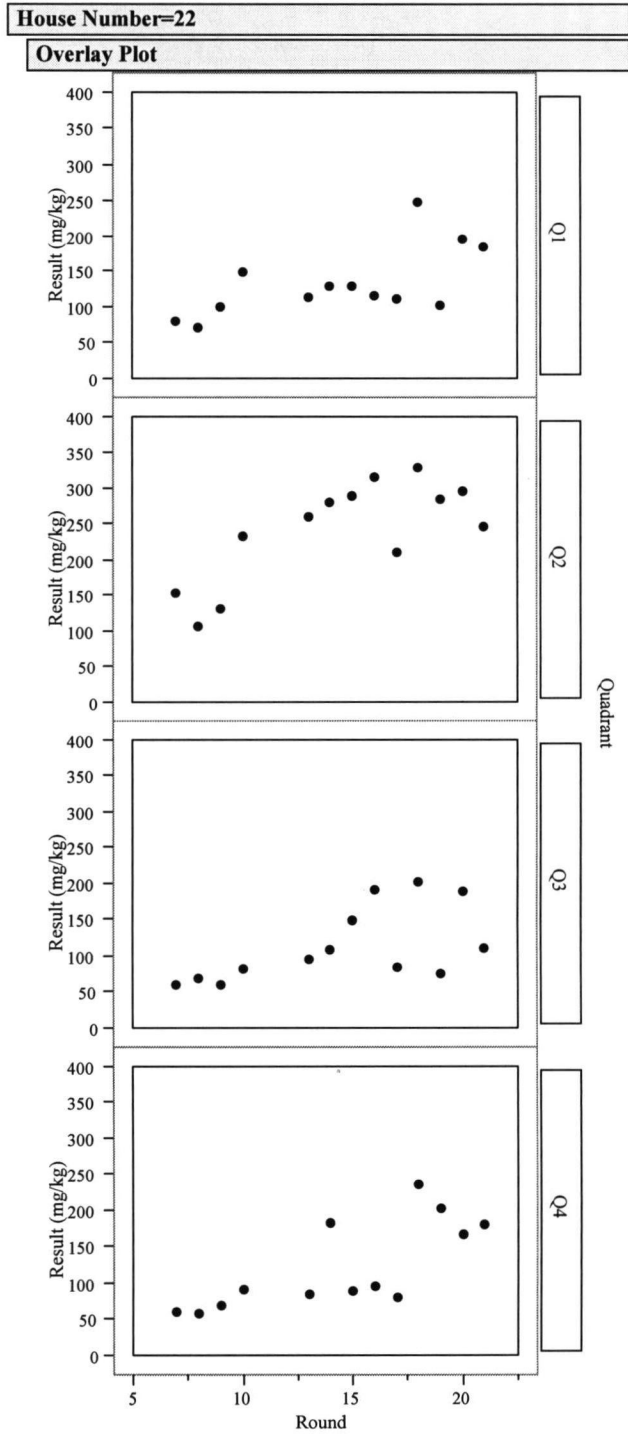
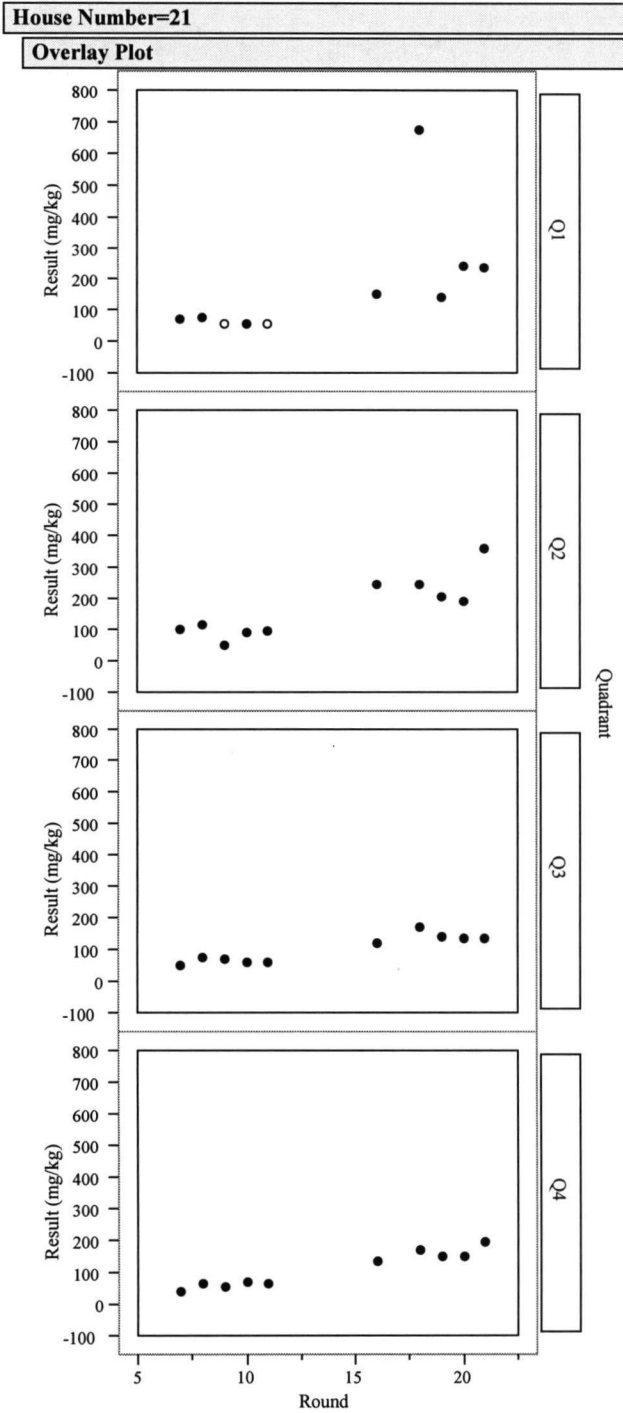


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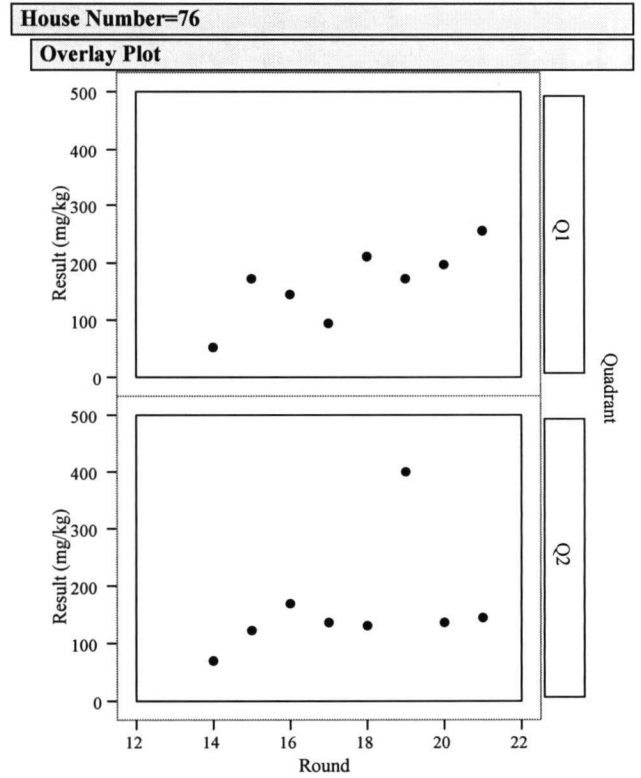
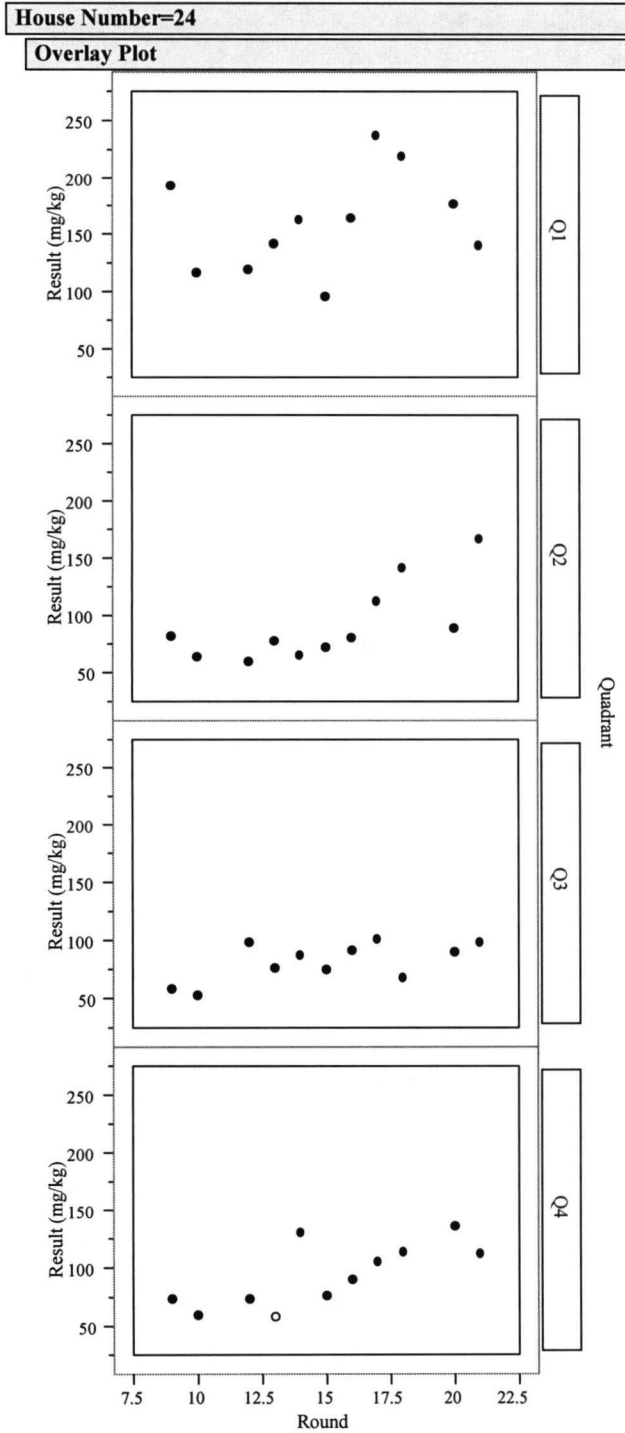


FIGURE 1. Lead Concentration Trends From Round 7 Through 21 (Continued)

